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ABSTRACT

Psychologists know that reasoning human beings do not spontaneously follow the rules of formal logic when using implication. Addressing this phenomenon, Piaget employed the concept of "significant implication," which exists when the meaning of a subsequent proposition is "included" in the meaning of an earlier one, and is not merely correlated. Appearing early in the development of the child, significant implication was thought to be the precursor to children's comprehension of necessity. Piaget also differentiated between proactive implications, which are reasons for preceding implications, and retroactive implications, which depend on the questions subjects are capable of asking as they work on understanding. Two studies were conducted to investigate whether individuals' capacity to correctly use implication is linked to possession, in a given situation, of a model organizing meanings in terms of reason. Results of a developmental study of children between 5 and 13 years of age indicated that their ability to manipulate implication depended on the richness of a model each subject had established or that he or she was capable of establishing. Adult subjects correctly manipulated implications when in a situation within which they could reorganize and/or transform meanings, as they searched for the reasons permitting them to do so. Implications of the findings for researchers are briefly discussed. (RH)

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THE LOGIC OF MEANING AND MEANINGFUL IMPLICATION

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Running Head: Logic of meaning

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Jean Piaget's last works and those of the Centre International d'Epistémologie Génétique were concerned with the cognitive rôle of Meaning and Reason. It is a well-known fact that the logical structures of thought whose development Piaget described were based on the logic of classes taken from the point of view of their extension and not that of their meaning. It is precisely on this extensional logic that mathematics is based on and Whitehead and Russel's Principia Mathematica is the classic reference. The last studies of the Centre were carried out in order to transcend such a theory and to study the complementary aspect of meaning and reason when the latter is taken as the implicit organisation of the former. This noteworthy change of viewpoint could remove some of the obstacles researchers interested in formal logic found themselves confronted with one way or another.

Indeed, long ago even the logicians found themselves in difficulty when faced with the paradoxical theoremes of formal logic and psychologists have long since realized that formal logic cannot offer a model of thinking. It is particularly the problem of implication that everyone has found themselves up against, although for different reasons (cf. Piéraut-Le Bonniec, 1980).

First, let's look at the problem from the viewpoint of a logician : in extensional logic, paradoxical theoremes stem from the fact that only the truth values of propositions are considered, and so operators are defined by their truth table. Thus, as it can be seen on table 1, the following implication is perfectly valid :

(1) "If water is made up of hydrogen and oxygen, Christmas day is December 25th".

Table 1

Many logicians have attempted to construct logical systems in which such an implication could not be possible and they have taken one of two directions. The first consists in trying to soften the opposition between True and False, either by introducing intermediate values between 0 and 1, like Łukaciewicz' 1/2 value (Łukaciewicz, 1953, 1970) or by introducing modulating operators (logical necessity and logical possibility) as Lewis and Langford have done (1932). The other direction - and it is the one that interests us here - is to try to reintroduce into extensional logic a portion of comprehension in the form of a relation called pertinence relation, i.e there must be something in common between p and q for the implication to be valid. This is what Anderson and Belnap (1962) have

attempted to do. Unfortunately none of these types of logic has been able to provide a satisfactory solution to the problems that they are supposed to solve and they, too, including Anderson and Belnap's, present their own paradoxical theoremes. Perhaps however, these attemps do hold some limited interest in that the mathematicians for whom such logics are constructed for, find them perfectly satisfactory as long as they are put to good use, that is, that one does not try to deduce the date of Christmas from the chemical composition of water.

The psychologist's problem is different : he believes that the logician is a human being like everyone else, i.e. that his nervous system is like every other person's ; thus it might be possible that the model of reasoning that he presents may be a model of thought processes, a bit as if they were offering up a treatise of virtue in the guise of a description of human behaviour ! In fact, by 1960, research into implication carried out in Geneva, and in particular that of Matalon (1962), had shown that this was not true. Since then, much research, that of Johnson-Laird and Wason among others (Wason , 1966 ; Wason & Johnson-Laird , 1968, 1972 ; Johnson-Laird , Legrenzi & Legrenzi, 1972) have confirmed that we do not spontaneously use implication following the rules of formal logic, in particular, when the relation between p and q is totally arbitrary, and

implication is reduced to its combinatory aspect. It was then asked if the results would be better if the implication subjects were offered were less arbitrary and less abstract and appertained to a topic the subjects were familiar with. It was, in fact, shown that a subject's knowledge of the problem, and in particular his experience with counter-examples, did have an effect on the results. A recent study by W. Overton shows, however, that things are not as simple as that (Overton , in press). In a field where it would seem teenagers do have some experience, only 22% of seventeen-year-olds gave a correct response. Would this mean that 78 % of the population in a country where children go to school until they are eighteen, do not arrive at the stage of formal logic? This is difficult to admit. It might mean that the problem must be posed differently. Thus, I would like to look at the work that was carried out by the Centre International d'Epistémologie Génétique over the last few years in the hope of shedding some light on this matter.

Piaget noted that the most fruitful endeaver undertaken by logicians to relate formal logic to natural logic was that of Anderson and Belnap who introduced the entailment operator. The use of such an operator is not pertinent unless the two propositions p and q have something in common. The distinction wich the logician makes between material

implication and the entailment operator would correspond to the difference between formal implication and what Piaget calls significant implication. Formal implication exists in situations where p and q are simply correlated, for example Matalon's set up where red and green lights go on and off according to an arbitrary rule chosen by the experimenter : "if the red light is on, then the green one is on". There is significant implication in a situation where the meaning of proposition q is "included" in the meaning of p. Piaget believes that such significant implication appears early in a child's development and that they are the precursor to the comprehension of necessity. Thus, it is very early in life that a baby understands that an attractive toy on a support implies that he can get the toy by drawing the support toward him. But the significant implication that guides the baby's behaviour supposes that the baby has understood the reason involved in the necessary relation. The test of the baby's understanding is that he does not grab the support if the toy is placed beyond it. Piaget emphasizes the fact that the real world does not present regularities that are more or less general ; it is the subject, who by his research into the reasons for a given state of things, invests them with meaning. In this way he constructs larger and larger models that permit him to progressively

eliminate what Piaget calls false necessities (Piaget, 1976), i.e. constraints that are not warranted by the subject's reasoning when his view of the situation is limited. These false necessities are progressively replaced by necessities whose reasons the subject understands by building up a system of meanings.

This was a new approach which implied new cognitive concepts. Unfortunately, except for his Essai sur la nécessité (Essay on necessity), which was published in Archives de Psychologie in 1977, in which Piaget introduced the notions of significant implication and reason, all that exists of his work on this subject are a few unpublished papers and the memory of our discussions on the subject at the Center, and so nothing proves that any of us have understood Piaget's thinking correctly. This is why I want to emphasize that although the ideas I am about to present here are fully dependent on the person we affectionately called "the Boss", I cannot be sure that they are faithful and I will assume the entire responsibility for what might appear inconsistent or uninteresting.

First I would like to clarify what I mean here by reason. The reason for which statement A is true must not be confused with the proof that a demonstration of the validity of that statement would offer. The reason is what allows us to understand the

meaning of A ; it is what explains A (cf. Halbwachs, 1981).

Let's take an example. Given two sets whose same number of items are arranged differently : in Set 1 they are in close proximity and in Set 2 they are far apart. We know that very young children think that the two sets are not equal in number (they often think that the set that takes up the least amount of space is also the smallest). It is not until a child is capable of making a one-to-one correspondence, even if it is by using his fingers, that he will be able to understand that the two sets have the same number of items. This is not a demonstration ; but the fact that to each item of Set 1 corresponds an item in Set 2 is the reason that the two collections have the same number of items. Statement A, "to each element of one set corresponds exactly one element of the other set", is immanent ot the meaning of Statement B, "two sets are equal", and a meaningful implication will join the two propositions because Statement A is correctly understood as the reason of B,

$$A \xrightarrow{R} B$$

and thus we can write : "p implies q, in meaning or significantly",

$$p > q$$

This relations is transitive if the meaning of a third statement C is included in the meaning of A and

B. For example, let C be the statement "the order in which the items of the two groups taken two by two is of no importance". This gives : "A is the reason for B and that is the reason for C",

$$(A \overset{R'}{\text{----}} B) \overset{R''}{\text{-----}} C ;$$

or p implies q and this implication implies r,

$$(p > q) > r$$

The second implication, in a way, is a consequence of the preceding one ; Piaget called this a proactive implication. But the subject might want to know the reason for the first significant implication ; he could then make up a statement whose meaning would include the meanings of A and B, for example, here, D = "A number (N) has necessarily one and only one successor which is that number plus 1". This is the reason that if for each item of a set there corresponds an item in the other set these two sets are equal :

$$D \overset{R}{\text{------}} (A \overset{R'}{\text{-----}} B) \overset{R''}{\text{------}} C$$

or

$$s > (p > q) > r$$

This implication is called retroactive ; it depends on the questions the subject is capable of asking as he works on understanding. It should be noted that Piaget had mentioned that this distinction between proactive and retroactive implication could already

by found in Pierce's work (predictive and retrodictive implications). Thus, referring to Johnson-Laird (1983), eliciting reasons can be said to be a construction of a model that relates previously formulated meanings.

But one problem still remains : Can the cognitive concepts that I have just presented account for any types of behaviour ? That is what I will try to demonstrate now. The difficulty such a demonstration represents can be stated in the form of the following question : Isn't the capacity to correctly handle implication linked to the fact that in a given situation the subject does or does not possess an available model which, in turn, presupposes an organization of meanings in terms of reason ? I will offer two examples that tend to show this is perhaps the case. The first is a developmental study on children that I carried out in Geneva at the Centre d'Epistémologie Génétique (Piéraut-Le Bonniec & Rappe du Cher, 1982) ; the other, on adult reasoning, was carried out by J.B. Grize and myself (1983) bu using different argumentation situations.

1. The length of the perimeter of a square

A square is a geometric figure ; in other words, it is a shape that is the result of properties that mathematicians have decided to give it. Squares are

not found in nature, but man may sometimes recognize in the real world shapes that resemble a square such as it is defined, i.e. an area bounded by four equal sides that meet at right angles. Any number that defines the length of the perimeter (P) of a square is equal to four times N, where N is the length of any given side (P = 4 x N and N = P / 4). We can, besides, introduce an additional constraint by stipulating that this number N be whole. Thus the number that defines the perimeter cannot be odd ; it cannot even be any even number ; for example, 20 works as it is made up of 4 x 5, but 18 does not (18/4 = 4,5).

It is in just such a situation that we have given children a problem of reasoning, as the elements that made up the perimeter of the squares that we used, could not be cut into smaller pieces. Thus the length of each rod serves as a single unit. Each square was defined by the number of rods per side and its perimeter was thus defined by a whole number of rods. Furthermore, these rods were solid and unbendable and could not be joined together in any way except at right angles or as a straight continuation of each other. Thus only squares or rectangles could be formed, but a lozenge could not.

- Figure 1

The subjects were shown the three models of squares that can be seen in figure 1. Their attention was drawn each time to the number of elements making up each side and to the total number of rods that were used to form the square. There were two experimenters. From a box containing a large number of rods, the subject and one of the experimenters (E_1) each took 4 yellow ones, 12 green ones and 2 blue ones, thus giving each one 18 identical elements (we checked that the subject knew how to count to 18 without problems). The other experimenter (E_2) then asked the subject a few simple questions of the types:

1) With what you have in front of you, could you make a small square with one rod on each side ?

2) With what he has in front of him, could Eddy = (E_1) make a big green square with three rods on each side ?

Then came the crucial question : "Do you think that with what Eddy has in front of him he can make a very big square with all his rods in such way that there won't be any left over" The subjects were expected to say that this was impossible, because if they made a square with 4 rods per side, there would be two left over, and if they made one with five rods per side, there would be two rods missing.

If the answer was correct, the experimenter E_1 mimed taking some rods out of the box which was

hidden behind a screen. Then he said to the subject : "Now I have enough rods to make a square bigger than all the ones we made before. How many rods do you think I have taken ?" The subject was expected to answer : "at least two, or six, or ten etc". Finally the child was asked what would happen if the experimenter took lots of rods, for example, 500 or 999 ,etc. "How do you know whether Eddy can make a very, very big square with all his rods in such way that there would not be any left over ?"

The subjects were grouped into three categories: the little kids (13 subjects between 5,0 and 7,5 years old), the middle kids (14 subjects between 7,6 and 9,11 years old), the big kids (14 subjects between 10,0 and 13,0 years old).

Five response levels were obtained in response to the crucial question.

Level 0

The problem is not undertood at all. There are two sorts of stereotyped responses : "It can be done because there are a lot" ; or, "it cannot be done because there are'nt many" or "there are'nt enough". When they were asked to try to make a square with their rods, the subjects put them end to end and then tried to close the figure. At this level, square means only closed shape with a rough relation between the size of this shape and the quantity of rods needed to make it.

Level 1

The subjects responded that they didn't know and that they would have to try. They then realized that it was not possible to make a square with 18 rods. They explain quite well that either there will be some rods left over or there will not be enough. However, they cannot say why. At this level, one of the fundamental properties of a square, i.e. that it has 4 equal sides, has been established and this constraint is felt very strongly. However the notion that the perimeter is equal to the length of the 4 sides has not been established and the subjects ask not questions concerning this. A square cannot be made with 18 rods because of the two disturbing rods that remain or are missing.

Level 2

The subjects accept to try not to use the rods and to work on imaginary squares. They reason with numbers by adding the number of rods needed for the sides, for example, 4 + 4 + 4 + 4, etc. They come to the conclusion that it is not possible to make a square with 18 rods but they cannot explain why, either. If they are asked if they can make a square with 19 rods, they start counting again, 4 + 4 + 4 +4, or 5 + 5 + 5 + 5, etc. At this level, the notion that the perimeter is equal to the sum of the lengths of the 4 sides of a square has been established. However the children do not relate the fact that a square has

four equal sides to the properties of the numbers that can be whole number measurements of the perimeter.

Level 3

The child responds by using the numeric property of evens and odds ; a square can be made if we have an even number of rods.

For example, Luc (11;2) said :

"4 on each side?no,there are too many...no,not enough ... ah, yes you can since it's an even number".

And for the question about 22 rods, he answered :

"Yes you can since it's an even number".

This child did not find it is necessary to check out his answer with the rods themselves. At this level, one of the geometric properties of a square has been related to one of the properties of those whole numbers that can be the length of its perimeter. A square is a shape whose elements are paired ; this appears in the manner the subjects often make a square. When asked to "try", they first make two sides that meet at right angles, and then the two other sides and finally they put the two pieces together. Thus, there is some symmetry in a square and this means that only even numbers can measure its perimeter. In terms of reasons, this can be written in the following manner :

A = The existence of some symetry in a shape

B = The number that measures this shape is even,

$A \xrightarrow{R} B$ (A is the reason for B).

And $(A \xrightarrow{R} B)$ is the reason for C :

C = A square has a perimeter whose length is an even number.

$$(A \xrightarrow{R} B) \xrightarrow{R'} C$$

Into the meaning of square is entered the meaning : "its perimeter is an even number". This gives the meaningful implication :

(2) "If a number is the length of the perimeter of a square, this number is even"

As it can be seen on table 2

Table 2

The first case (N is the length of the perimeter of a square and N is an even number) is verified for 16, 20, 24, etc. The case 2 would invalidate the implication if it were found in the experimental situation, but it is not, since the elements cannot be cut. So this case is not informative for the subjects. The case 3 (N is not the length of the perimeter of a square and N is an even number) is found in the experimental situation: 18 is an example of this situation : but it does not invalidate the implication and it is no longer informative. It is the converse implication, "if a number N is even, then this number is the length of the perimeter of a

square" which is informative : the subjects realize the difficulty of answering the question, because there is not equivalence between the two propositions:

N is an even number, and

N is the length of the perimeter of a square.

This appears in the responses of Stephane (8;11):

E2 : "And if you had 25 rods ?"

S : "You can't"

E2 : "Explain"

S : "No, you can't, because there'll be one left;you need an even number".

E2 : "Well, how about 22 ? Does that work ?"

S : "No, it doesn't make a square because you can have 5 on each side, and there would still be some left over"

E2 : "But it's an even number."

S : " Maybe you need 26 ?"

E2 : "Why would it work with 26 ?"

S : "Because 12 plus...because if you put 6 on each side, that makes 24 ; non, you can't".

E2 : "But it's an even number".

S : "Yeah".

E2 : "So your idea doesn't work. How do you know if a number works ?"

S : "I don't know... I count them, and if it doesn't work, it doesn't work".

The subject has understood that the second case (N is an even number and N is not the length of the perimeter of a square) invalidates the implication that had served as his guide until then. The difficulty made some subjects reconsider theire reasoning, for example Sebastien and Cyril,

Sebastien (10;4) :

E2 : "Do you think he can make a square with all his pieces ?"

S : "Yeah"

E2 : "Why ?"

S : "Well, because it's even"

E2 : "How many rods will the square he makes have on each side ?"

S : "5...", No, because that'll make 20 and he has 18 altogether. I don't think he can do it".

E2 : "Why ?"

S : "Because you can't, because 18 can't be divided by 4".

E2 : "Before you said that you had to have an even number;does it work with 22 ?"

S : "No".

E2 : "Why ?"

S : "Because there would be two too many".

E2 : "With 26 how do you know if you can make a square ?"

S : "I'd use a two's table",

E2 : "And with a two's table do you think you would know if you could make a square with 26 rods" ?

S : "I don't know"

E2 : "Isn't there a better table ?"

S : "Oh yes, if you can divide by 4 you know that you can make a square ; yeah, sure, 26 can't be divided by four".

Cyril (10;10)

"You have to have an even number... but you have to try it out to see ; I can do it with multiples of 4... and multiples of 4 are always even numbers."

Level 4

The child uses divisibility by 4. He has understood that we were working with a general rule that was good for any number no matter how high it was ; all he had to do was check to see if it was a multiple of 4.

Robert (9;10) :

E2 : "With 44 what must you do to know ?"

S : "44...44,... you need 4 times something but it's not sure that it'll work... ah, you can do 4 times 11"

E2 : "And can division help ?"

S : "Yeah, you see if you have 0"

François (12;0) :

E2 : "For example, with 950 what would you do to know if you could make a square using all the rods and with no rods left over ?"

S : "I divide by 4".

At this level, the square is seen as having double symmetry. It has four equal elements and in terms of reasons we have :

A = A shape is bordered by 4 equal sides

B = Its perimeter is a multiple of 4

$$A \overset{R}{\text{------}} B$$

C = The length of the perimeter of a square is a multiple of 4

$$(A \overset{R}{\text{------}} B) \quad \overset{R'}{\text{-------}} C$$

Into the meaning of square is entered the meaning "its perimeter is a multiple of 4". An we have the meaningful implication :

(3a) "if a number is the length of the perimeter of a square, then this number is a multiple of 4".

We will call it the "direct significant implication" in that it is directly generated by considering a specific property of the squares. Let us consider now the converse implication which is one that answers our question ("can he make a square with 18 rods in such way that there won't be any left over?") :

(3b) "if a number is a multiple of 4, then this number is the length of the perimeter of a square".

Table 3

As we can see on table 3, case 1 holds true in direct and converse implication. Case 2 and 3 are more complex.

Case 2 : direct implication : N is the length of the perimeter of a square and N is not a multiple of 4 is impossible in the experimental situation and the subjects at this level know the reasons why ;

converse implication : N is a multiple of 4 an N is not the length of the perimeter of a square : it does not come up in the experimental situation, as it is presented to the subjects, for the following two reasons : the rods can only be assembled at right angles and it was decided that only squares would be made. But other experimental situations could exist, where other geometric figures were allowed, such as diamonds or rectangles (16 could be the perimeter of a rectangle whose sides have the length of 3 and 5 : 3 + 3 + 5 + 5).

Case 3 : direct implication : N is not the length of the perimeter of a square and N is a multiple of 4 = converse implication case 2.

converse implication : N is not a multiple of 4 ans N is the length of the perimeter of a square ; it does not come up in the experimental situation for the following reason : the rods cannot be divided ; but in a situation where the rods could be cut up, 18 would be an acceptable number as it is the product of 4.5 multiplied by 4.

It would be interesting to see how a 5th level would be structured in relation to a generalization of the model, i.e. in relation to the subject's

understanding of other geometric forms and other number properties.

The distribution of the levels as a function of age is given in table 4.

Table 4

What do these results mean ? The notion whose development we have studied concerns the link between a geometric property and a numerical one. It is the establishment of these two properties and of their intersection that permits the child to give the reason why a number can or cannot be the length of the perimeter of a square. The point of interest then was to see what information the children took out of the situation and what questions they asked.

As it can be seen, the ability to correctly manipulate implication depends on the richness of the model the subject has established or that he is capable of establishing in a given field, i.e. the ability to detect the reasons an implication might be invalid (case 2) and the reasons for which p or q could be true or false.

2. An example for argumentive reasoning

I would now like to show quickly how adult subjects manifest their comprehension of an implication in argumentive situations. J.B. Grize

and I have studied how contradiction is used in argumentation. One of the best ways to demolish an adversary is to prove that what he has said is contradictory or that his actions contradict what he says. We carried out this study by analyzing various types of articles in the press : political or scientific texts and even a few novels like the one I am about to discuss. Our rules was that the author had to explicitly deny a contradiction and [redacted] to explain what it consists of. These texts were then presented to subjects who were asked if the author was right, and if he wasn't, to explain in what way they thought he was wrong. As we often chose controversial texts, we had subjects who invested strongly into the discussion.

Here is one of the texts :

"Everytime Antoine thought of Jacques' ideas, he found himself up against a fundamental contradictions : how could his brother who hated violence with the passion of all his intelligence and being - and he had proven this when he did not hesitate to sacrifice his life to preach brotherhood and to sabotage the war - how could he have, for years, militated in favor of social revolution, which is the worst kind of violence there is". (Martin du Gard, Les Thibaut).

It must be remembered that in the novel Jacques died by dropping anti-military tracts over the French

and German lines at the beginning of the first World War.

Before making his remarks on his brother's conduct, Antoine found the following implication valid :

(4) "If one hates violence, then one does not militate in favor of social revolution" (see table 5).

Table 5

If this implication is true, then q is expected (="one does not militate in favor of social revolution"), and if $\sim q$ obtains (="one does not militate in favor of social revolution" is not the case), the validity of the implication becomes questionable. Half of the subjects to whom this text was presented agreed with the author and, consequently, did not question the implication and gave reasons for it. However the other half tried to show this was not contradictory and thus show that Jacques' conduct was coherent. Some subjects began by saying, "there are people who like violence, but who aren't in favor of social revolution". This is the third case. But they do realize that this does not solve the problem and that the real solution lies in discrediting the implication ; thus the subjects sought reasons to justify case 2 : there is somebody, Jacques for example, who hates violence and does militate in favor of social revolution. Among the

most often cited reasons was the idea that there are different types of violence and some of these, while they might not be good, would at least be acceptable: for example the violence necessary to bring about a social revolution, which would be a way to prevent foreign wars, is an acceptable type of violence. The solutions chosen by the subjects to defend the coherence of Jacques' conduct was, in fact, of little concern to us here. What is important is how the subjects correctly manipulated the implications when in a situation where they could (re)organize and/or transform meanings as they searched for the reasons that permitted them to do so.

CONCLUSION

I am quite aware of the poverty of the research I have just presented ; it cannot be compared to research whose experimental conditions allow the data to be treated by an ANOVA. However, the interest of this work, I believe, is to show that the reasoning a subject is observed to carry out cannot be dissociated from that subject's knowledge of the topic under consideration. Moreover, I think one must always ask what kind of meaning the experiment holds for the subject. I would like to take up here a few classic examples. Given an experimental situation that puts the subject to work on the following implication : "If a card has a vowel on one side,

then it has an odd number on the other side". Unless the subject has been trained in this type of play activity, he is quite surprised ; what kind of meaning or reason could justify such an implication and what reasons could invalidate it ? The subject then turns the cards over arbitrarily. As a second example, let us take the situation set up by Cox and Grigg (1982) and which was used again by Overton (in press). The subject is presented the following implication : "If a person is drinking beer, the person must be over 21". Here again the subject is asked to find the cases that render the implication invalid. To do so, I think that the subjects imagine they are policemen who must make a round of the bars to see if the law is being correctly observed. They make sure that the people drinking beer are at least 21 and that those who appear younger do not drink beer. For the subject, the problem under these conditions is not to know whether the implication holds, but to be sure the law is observed. Now take the example of the following implication that was also offered by Overton (in press) to his adolescents : "If a student has more than 10 absences in a school year, the student must repeat the school year". This problem puts the students in a very difficult position. In fact, they have no reason to question the application of such a decision that was made by the school authorities. Anyone under 21 might

disobey the law and drink beer, but students are not at all free to refuse to be kept from passing into the next grade if their teachers have decided they must be kept back. The rule can neither be questioned nor transgressed ; confused, the subjects turned their cards over at random.

I think that, in fact, by the time a child reaches his teens, he is able to reason according to rules for which formal logic might be considered to be an abstract model of. But this would be true only under the condition that the reasoning is to be applied to fields that the subjects have knowledge and experience of and in situations that make sense to them.

If we accept that intelligence is the most highly developed adaptation to life that nature ever invented, I believe that reasoning must be studied in situations that mean something to the subject. I only hope that the introduction of the notions reasons and significant implication, which I have very clumsily presented here, lead to new, more rigorous research which can only be beneficial to our understanding of the human mind.

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	p	q	$p > q$
	"A number N is the length of the perimeter of a square"	"This number N is even"	
case 1	true	true	true
case 2	true	false	false
case 3	false	true	true
case 4	false	false	true

' > ' meaningful implication operator

Table 2.- Proposition 2 truth-table. "If a number is the length of the perimeter of a square, then this number is even".

(a) Direct significant implication

	p	q	$p > q$
	"A number N is the length of the perimeter of a square	"This number is a multiple of 4"	
case 1	true	true	true
case 2	true	false	false
case 3	false	true	true
case 4	false	false	true

(b) Converse implication

	p'	q'	$p' > q'$
	"A number N is a multiple of 4"	"This number is the length of the perimeter of a square	
case 1	true	true	true
case 2	true	false	false
case 3	false	true	true
case 4	false	false	true

'>' meaningful implication operator

Table 3.- Propositions 3a and 3b truth-tables. Direct significant implication: "If a number is the length of the perimeter of a square, then this number is a multiple of 4".

		Levels				
Ages		0	1	2	3	4
5;0 - 7;5	(n = 13)	.61	.30	.07		
7;6 - 9;11	(n = 14)		.35	.35	.14	.14
10;0 - 12;11	(n = 14)			.07	.28	.64

Table 4.- Distribution of the levels as a function of age

	p	q	$p > q$
	"One hates violence"	"One does not militate in favor of social revolution"	
case 1	true	true	true
case 2	true	false	false
case 3	false	true	true
case 4	false	false	true

' > ' meaningful implication operator

Table 5.- Proposition 4 truth-table. "If one hates violence, then one does not militate in favor of social revolution".

Figure 1.- The three models of square